Thinking Differently: Developing a New Energy Economy

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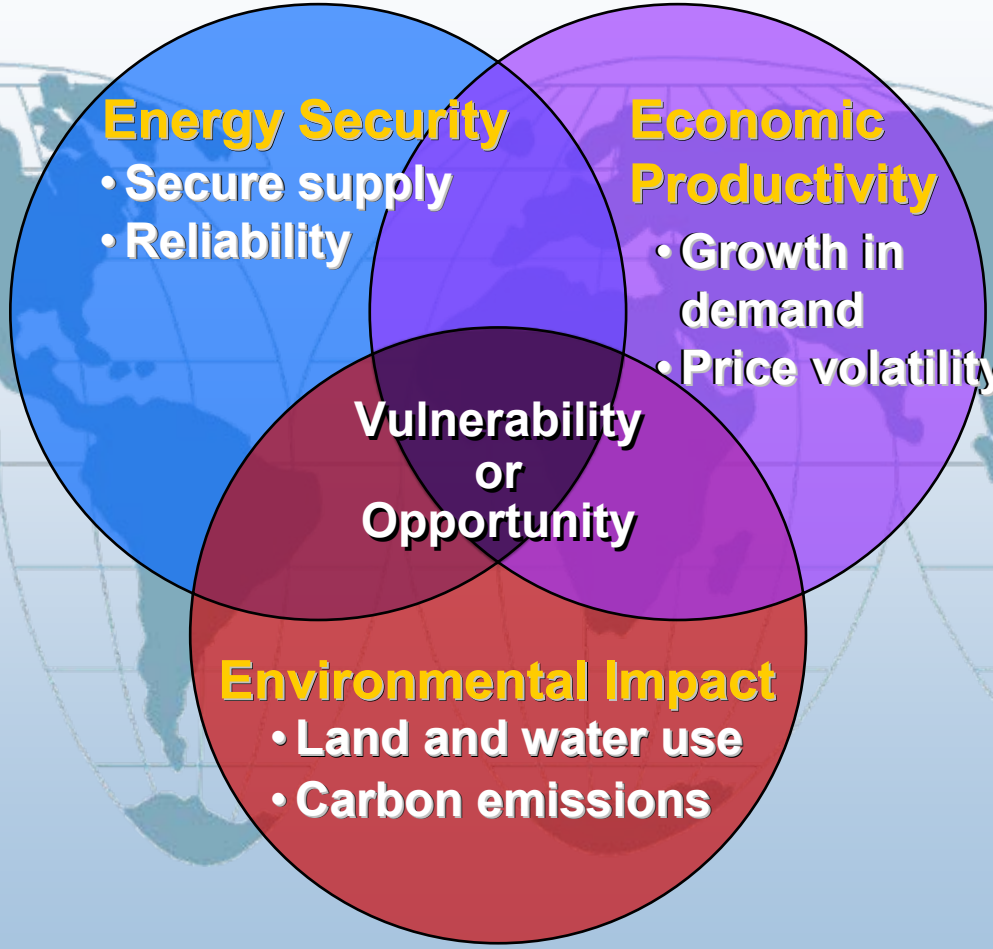
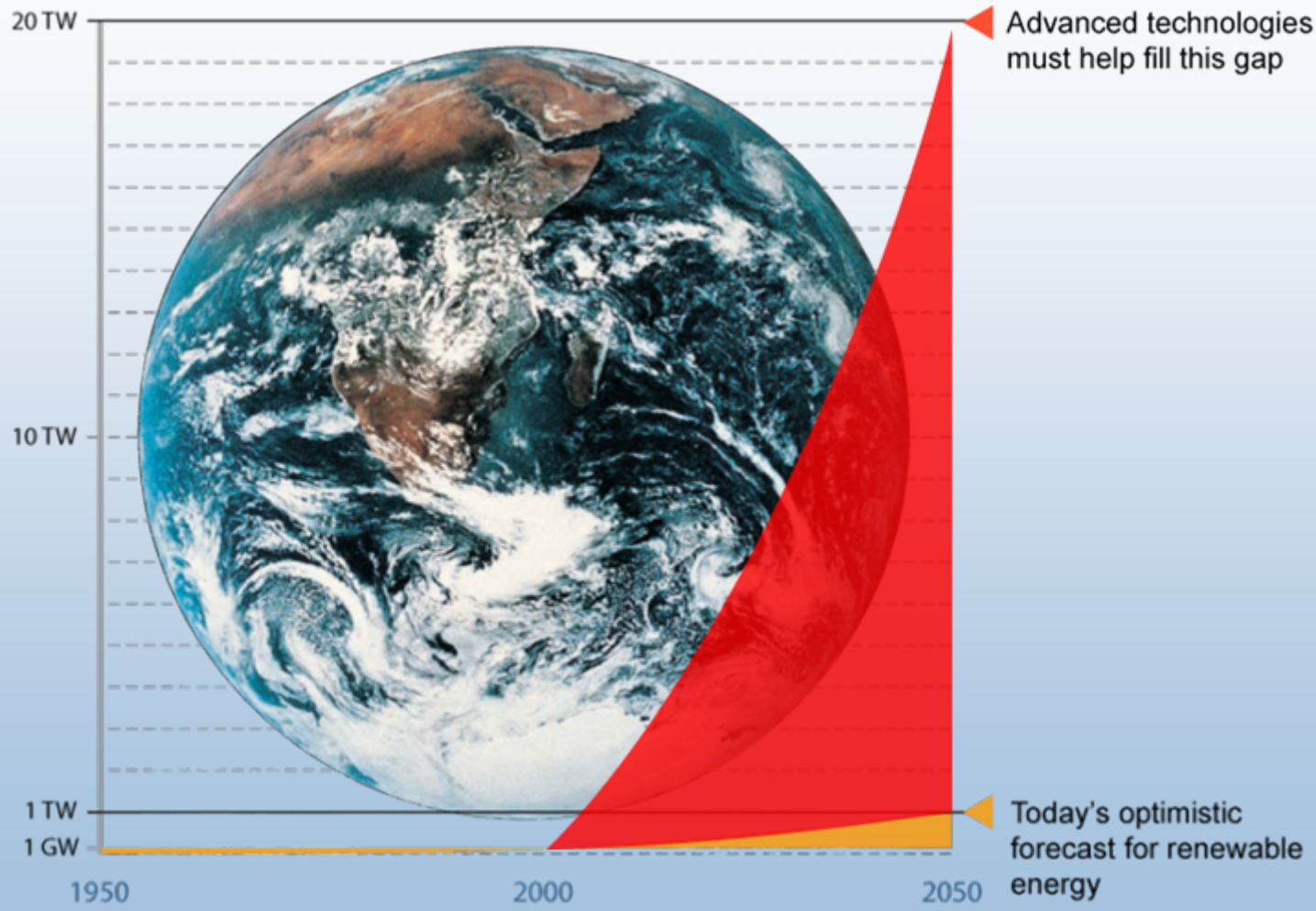
Energy Solutions Are Enormously Challenging



Must address all three imperatives

How Big is the Challenge?

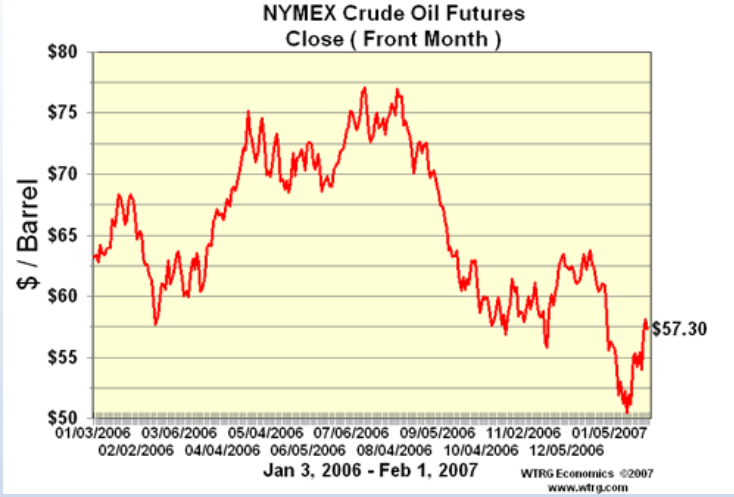


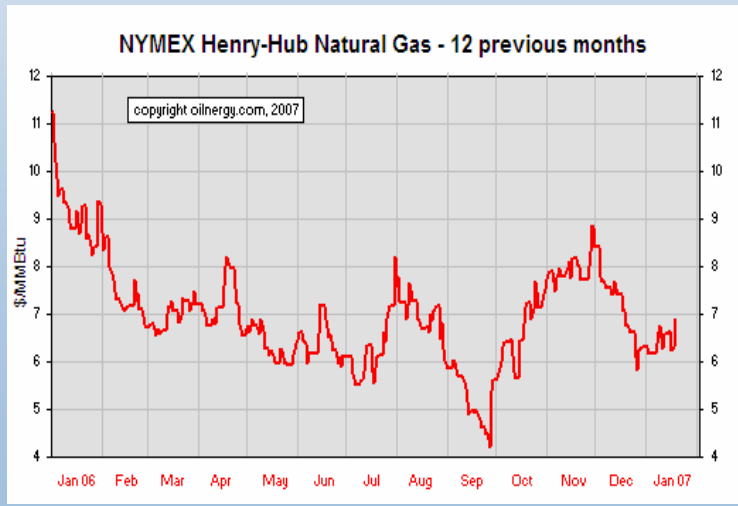
Source: Arvizu, NREL

Thinking Differently: Account for Externalities

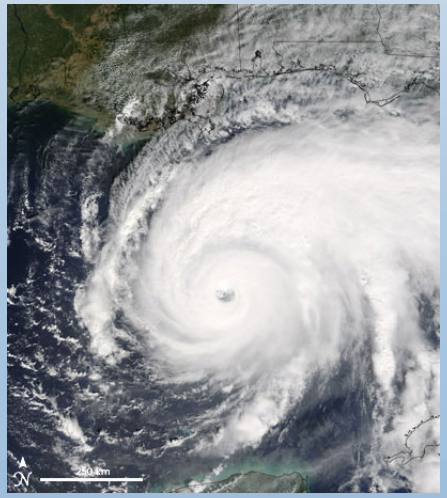
Today's energy marketplace does not appropriately "value" certain public objectives or social goods, instead we have:

- Price volatility
- Serious environmental impacts
- Underinvestment in energy innovation

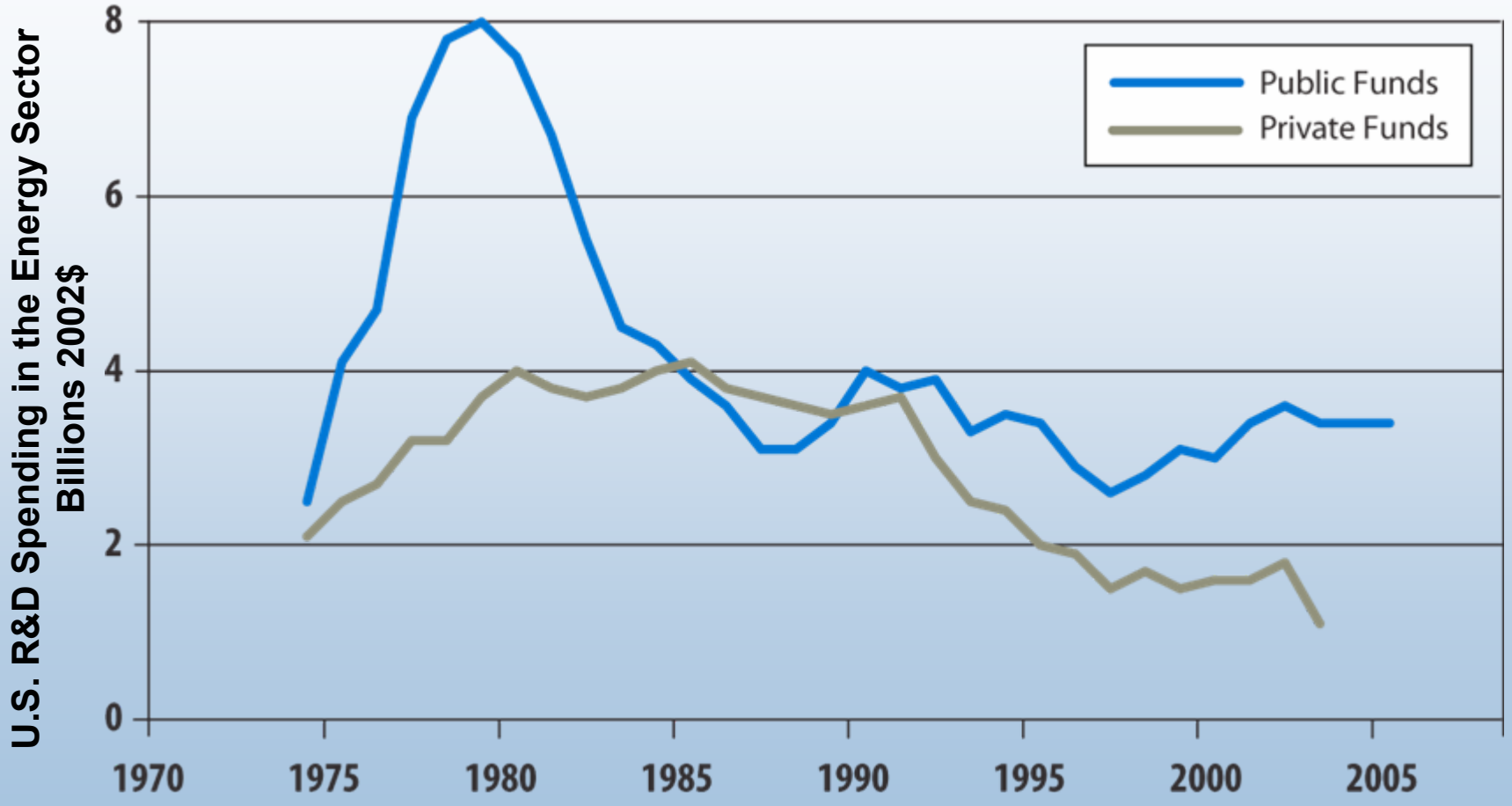




Mounting Evidence…

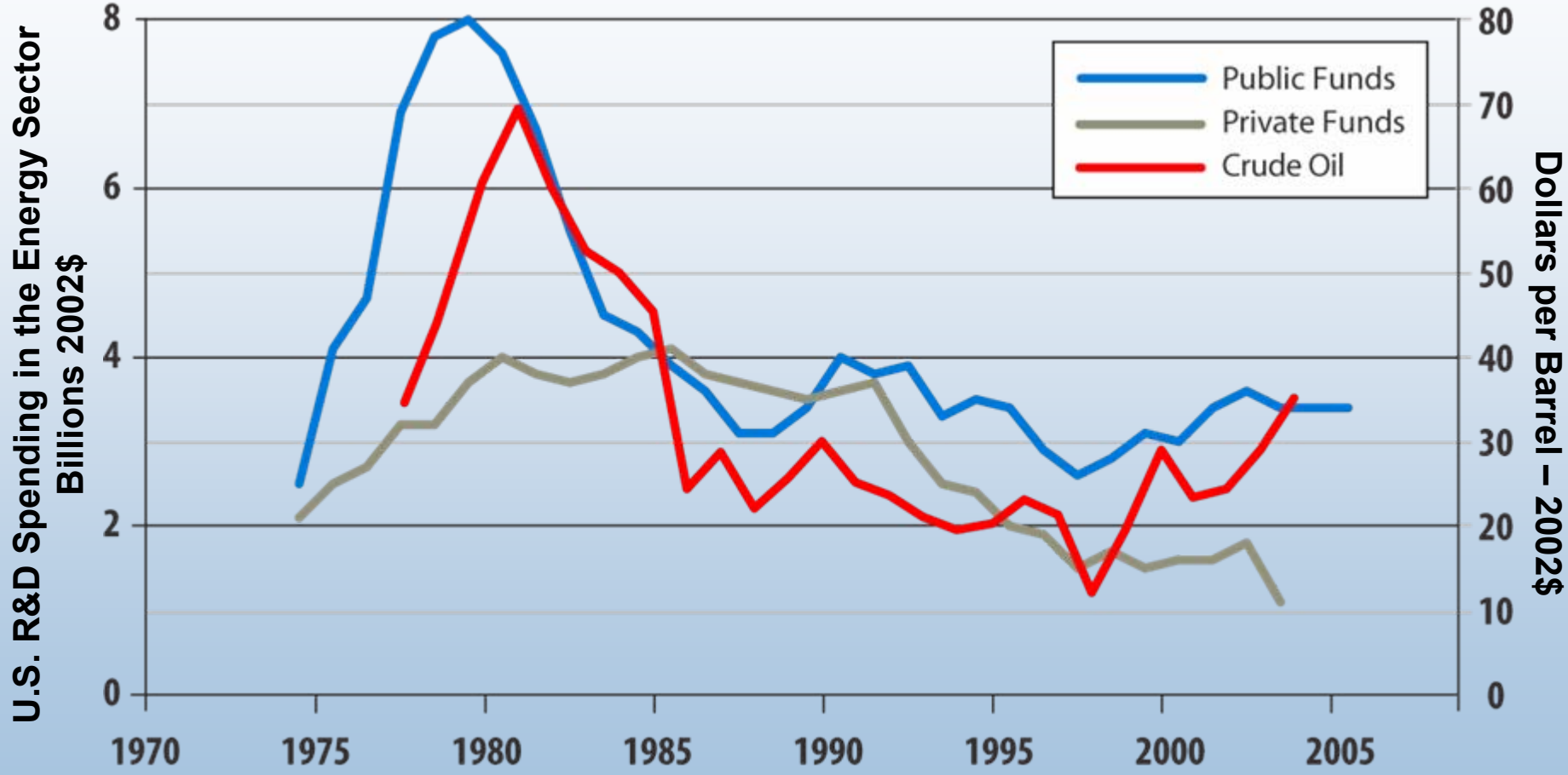


Declining Energy R&D Investments…



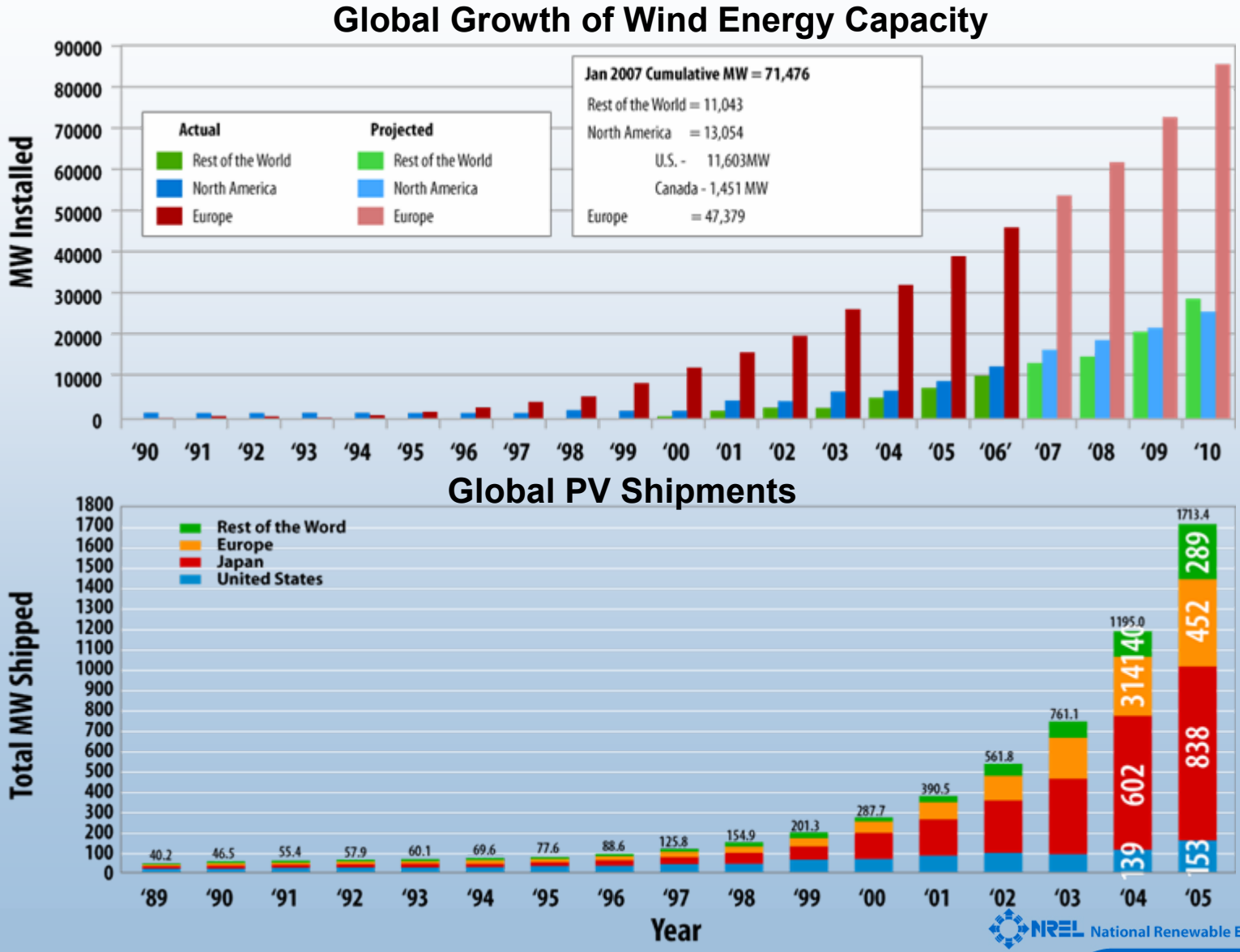
Source: Daniel Kammen, Gregory Nemet *Reversing the Incredible, Shrinking Energy R&D Budget* http://rael.berkeley.edu/files/2005/Kammen-Nemet-ShrinkingRD-2005.pdf
Table 10.3, Edition 25, *Transportation Energy Data Book* http://cta.ornl.gov/data/chapter10.shtml

Declining Energy R&D Investments… Reflect World Oil Price Movement



Source: Daniel Kammen, Gregory Nemet *Reversing the Incredible, Shrinking Energy R&D Budget* http://rael.berkeley.edu/files/2005/Kammen-Nemet-ShrinkingRD-2005.pdf
Table 10.3, Edition 25, *Transportation Energy Data Book* http://cta.ornl.gov/data/chapter10.shtml

Global Markets are Growing Rapidly



Getting to "Significance" Involves…

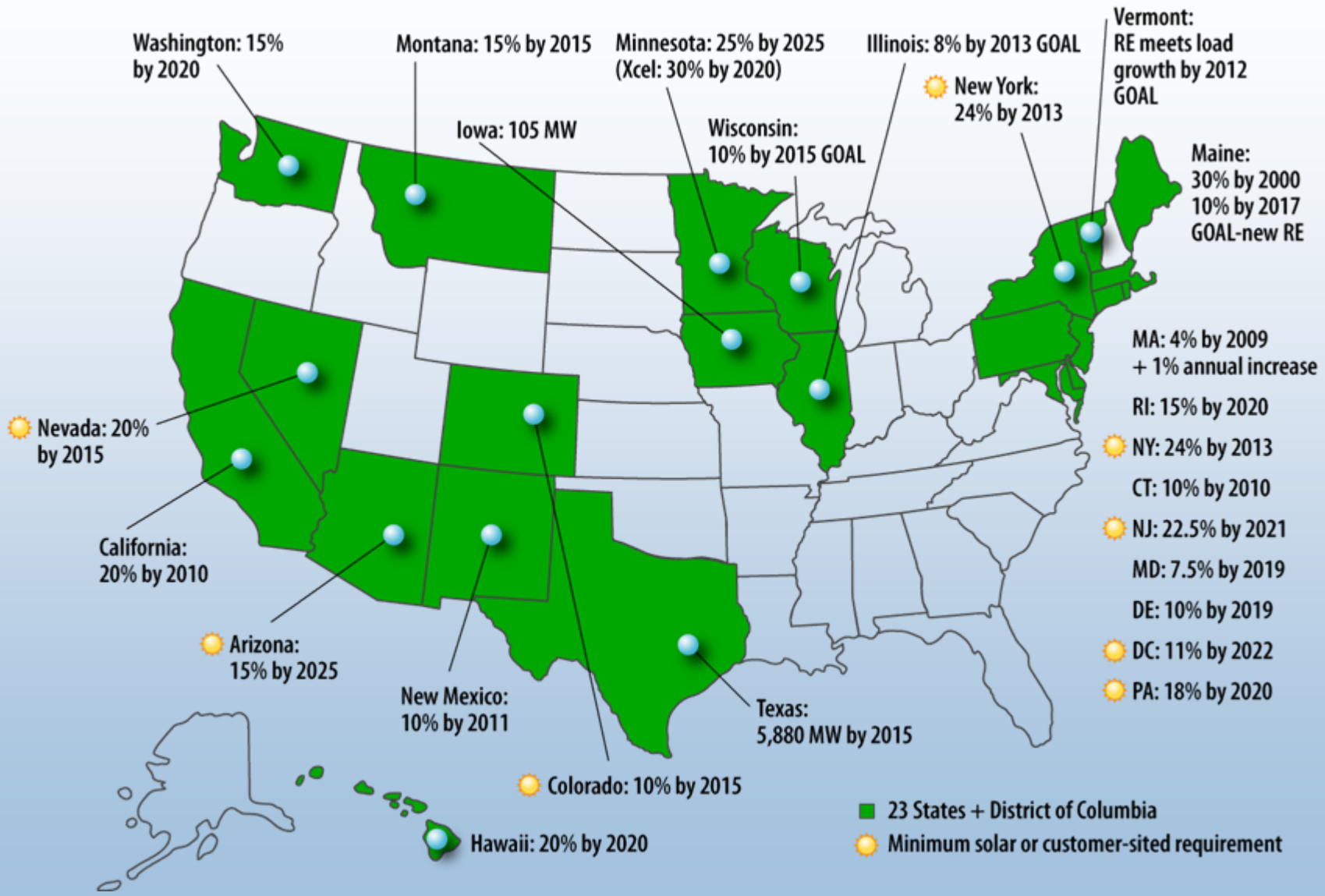
Source: NREL

Setting the Bar Higher

- **U.S. National goals**
  - Biofuels: reduce gasoline usage by 20% in ten years
  - Wind: 20% of total provided energy by 2030
  - Solar: Be market competitive by 2015 for PV and 2020 for CSP
- **Challenge goals**
  - 25% of nation's energy supply from renewable sources by 2025
  - Others…

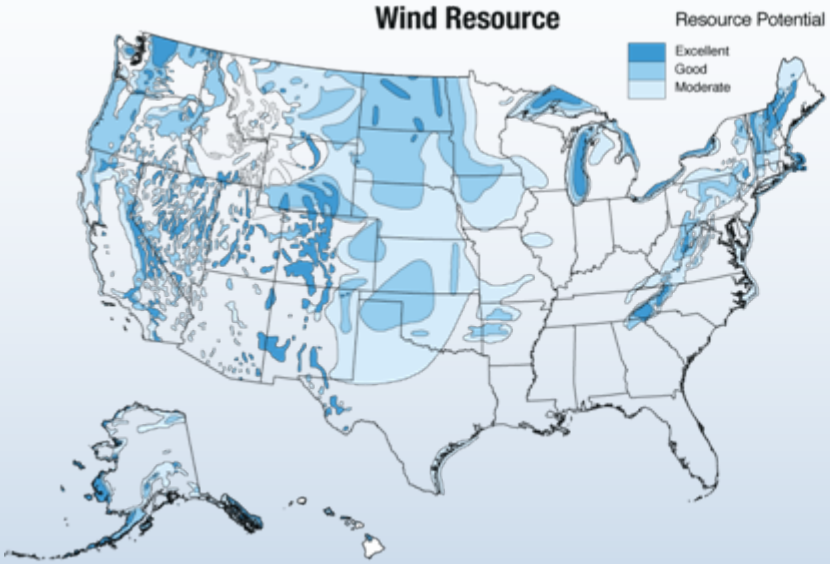
State Policy Framework

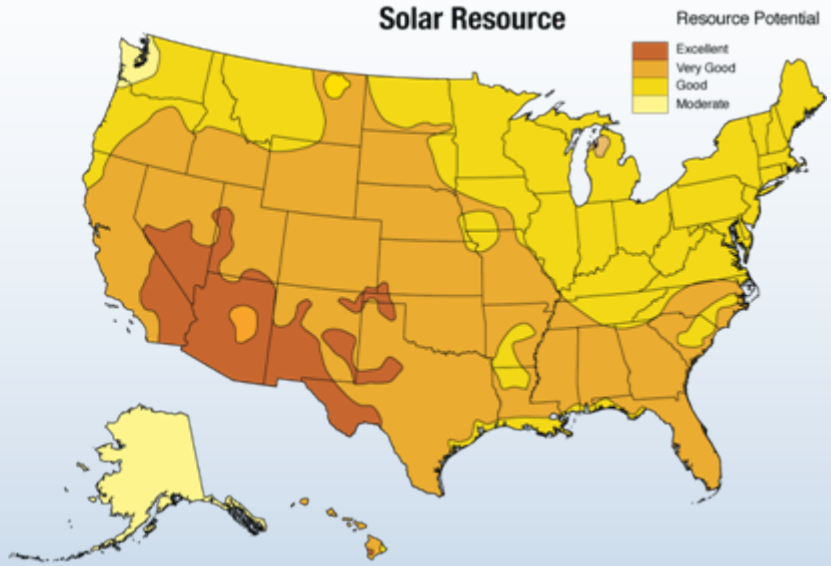
Renewable Electricity Standards

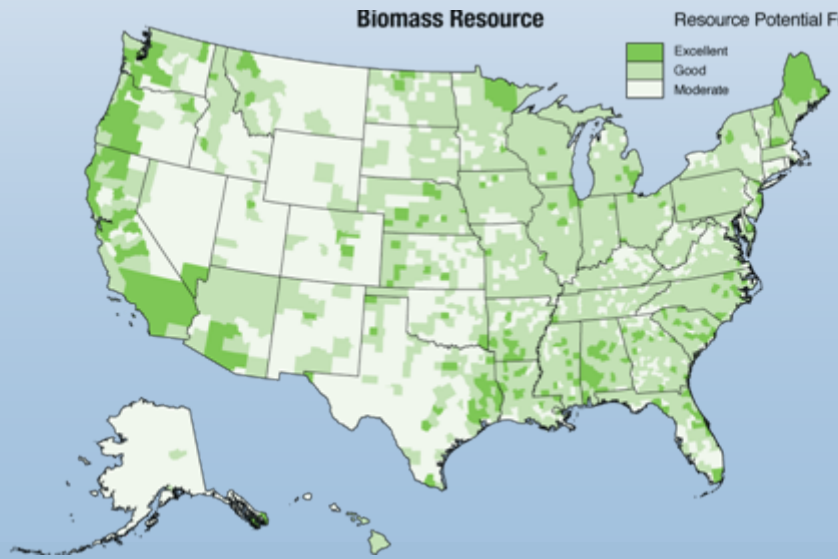


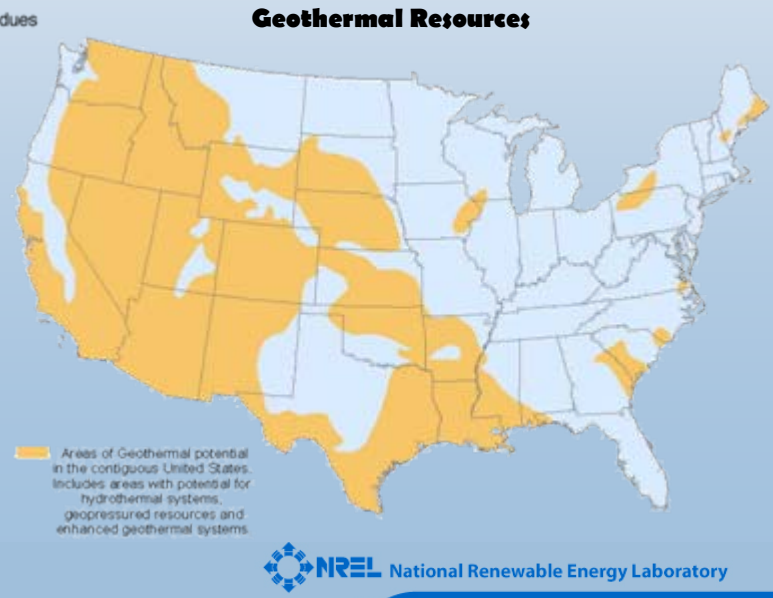
Source: DSIRE database, March 2007

National Resources



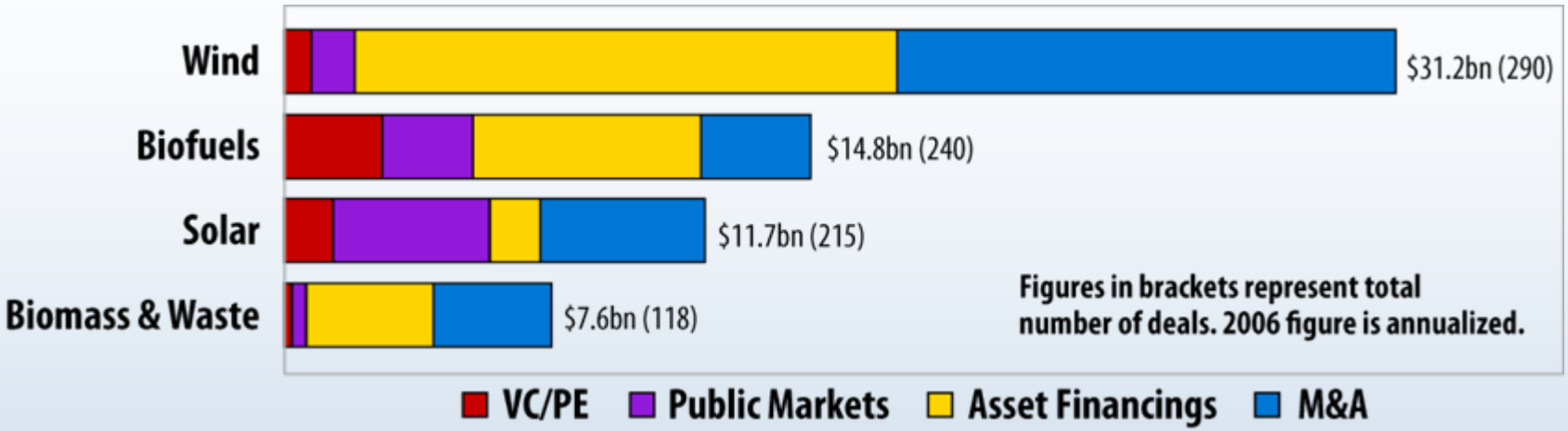




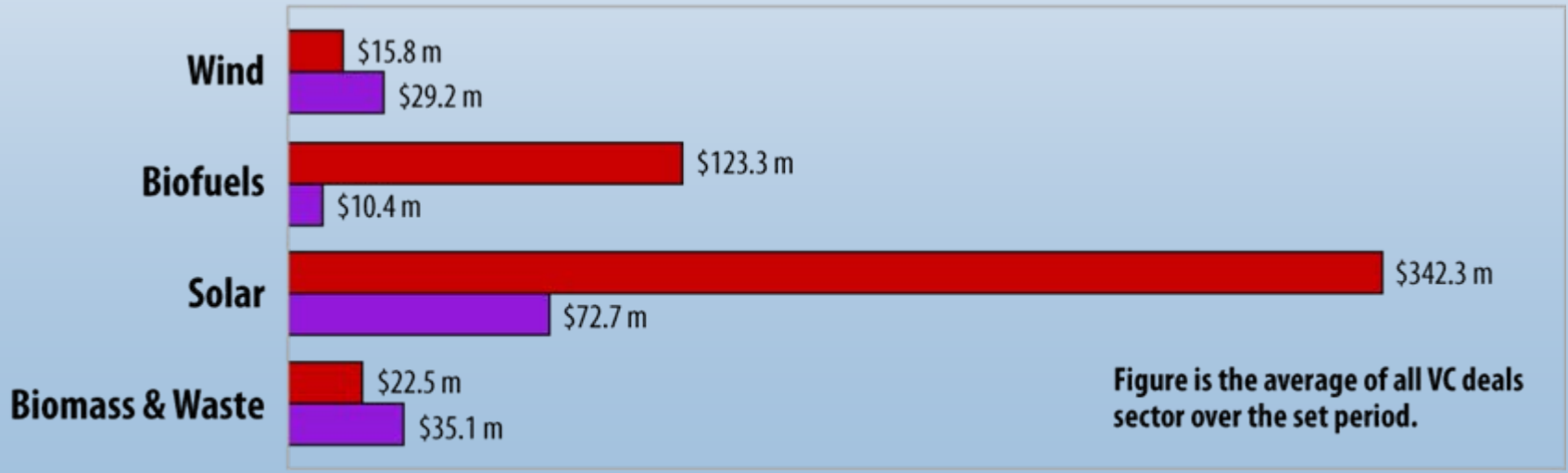


Money Is Flowing Into the Sector

2006 Investment and M&A – By Sector and Asset Class

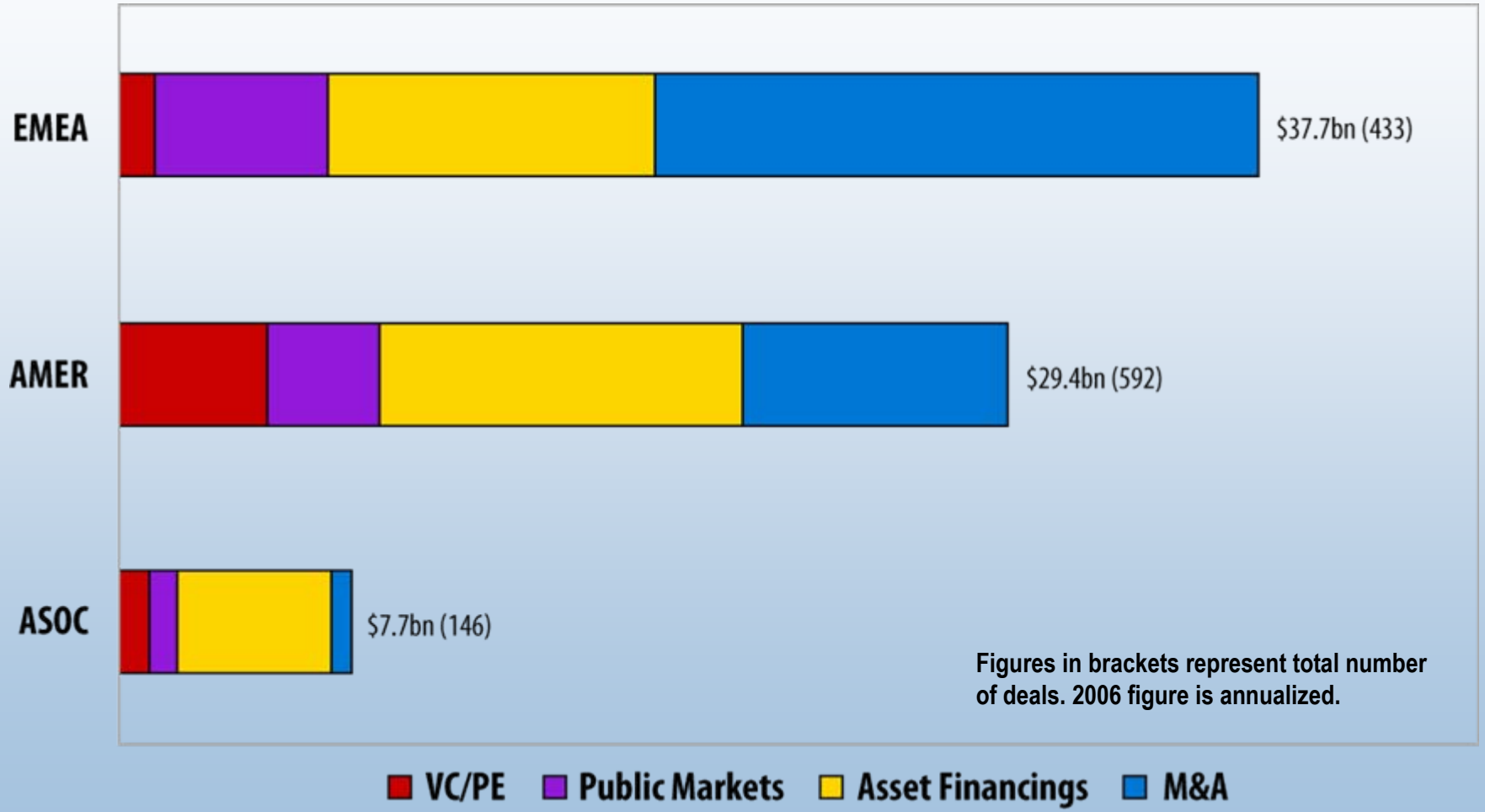


Annual VC Investment Volume – 2001-2004 Compared With 2005-2006



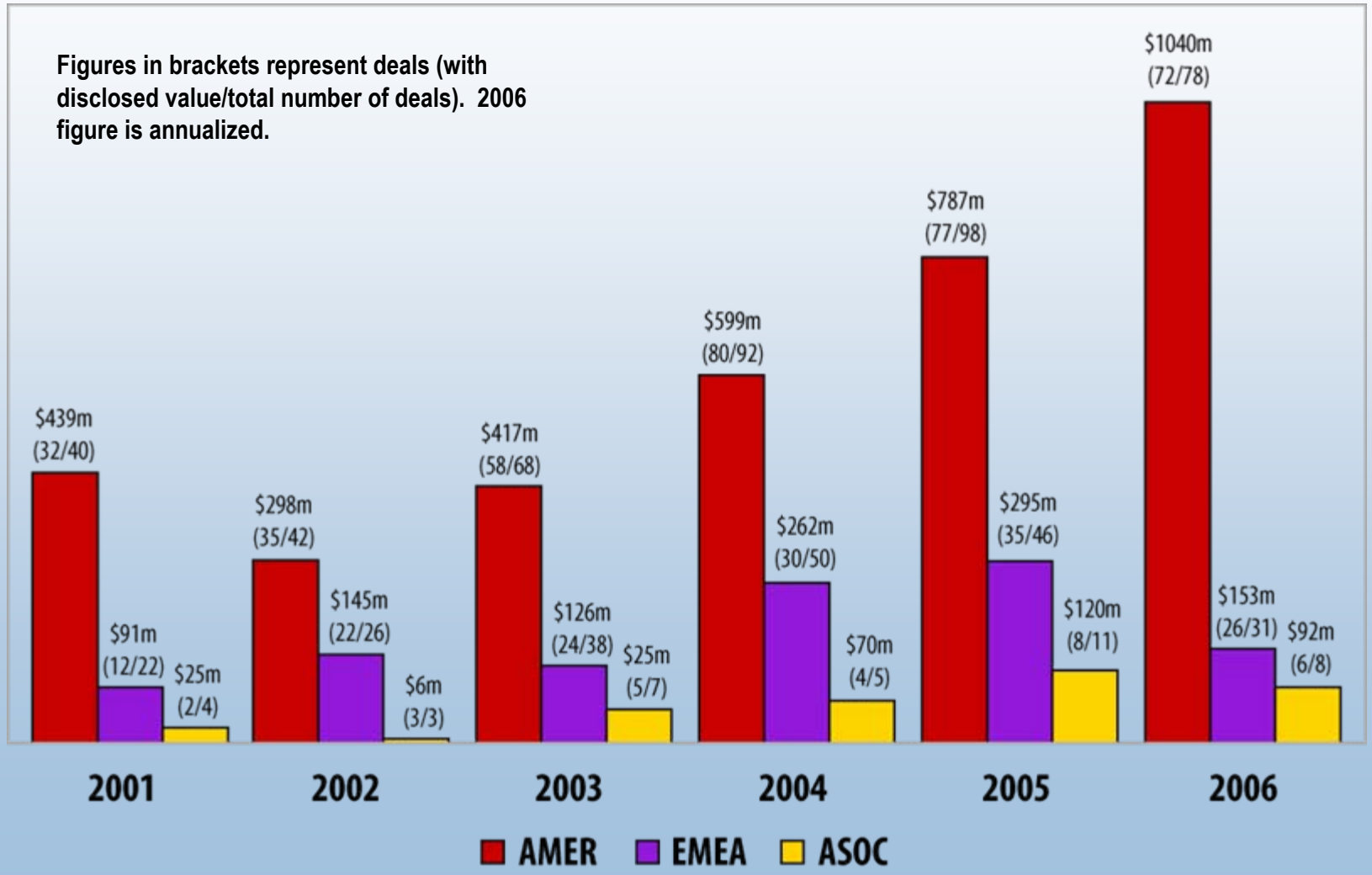
Source: New Energy Finance 2007

Investment and M&A
By Region and Asset Class – 2006



Source: New Energy Finance 2007

Total Estimated VC Investment by Region 2001-2006

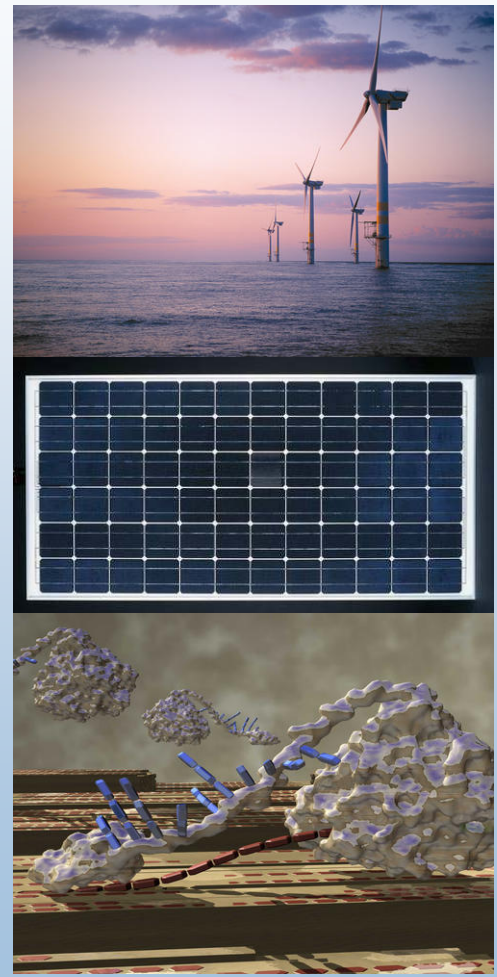


Source: New Energy Finance, January 2007

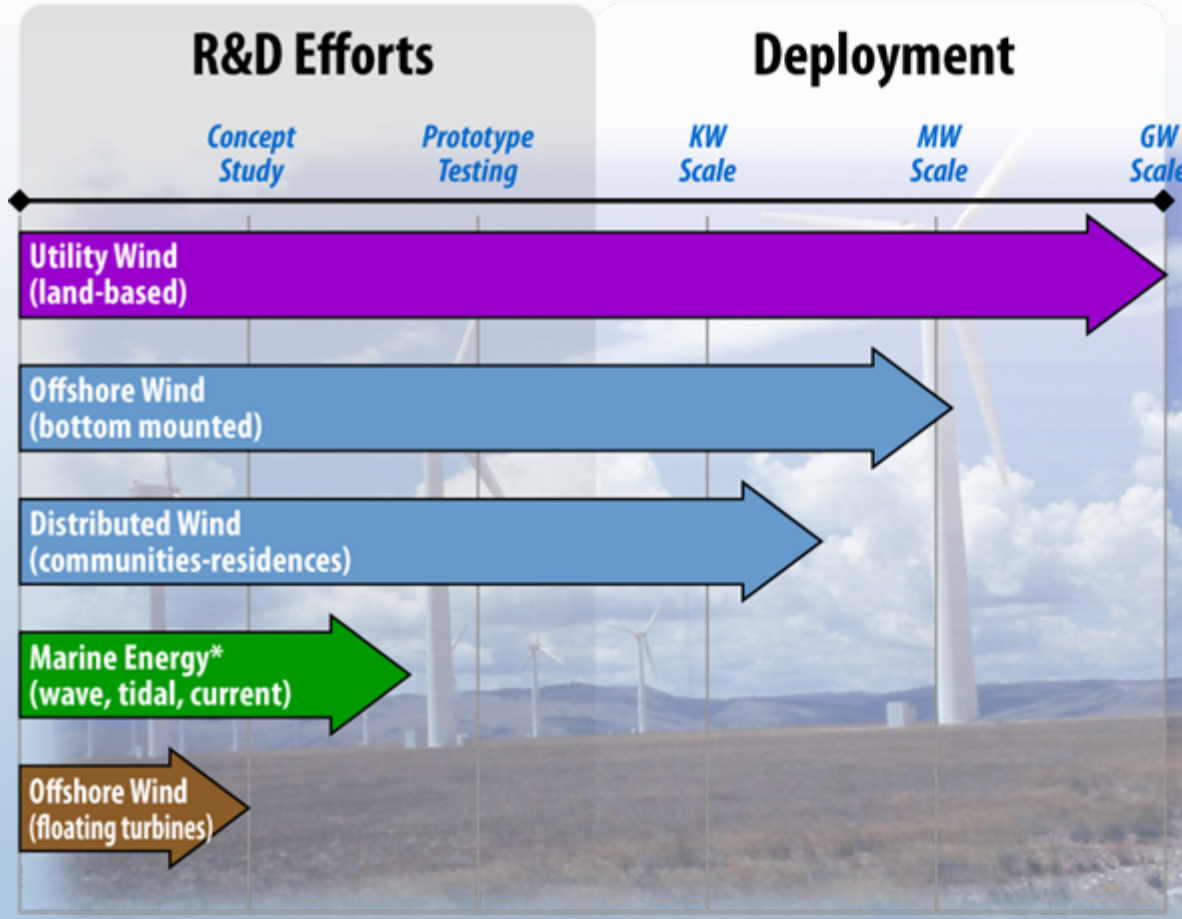
Technology Innovation Challenges

The Next Generation

- Wind Turbines
  - Improve energy capture by 30%
  - Decrease costs by 25%
- Solar Systems
  - Improved performance through, new materials, lower cost manufacturing processes, concentration
  - Nanostructures
- Biofuels
  - New feedstocks
  - Integrated biorefineries



Wind and Marine Energy R&D



Key Technology Drivers	Attributes
• Cost/kWh • Transmission • Reliability • Permitting/Siting	• Increased area of use • Lower cost
• Permitting • Reliability • Access • Cost/kWh	• Becomes cost competetive • Increased area of use
• Capitol Cost • Cost/kWh • Reliability • Permitting	• Improved cost & reliability • Wide spread use
• Survivability • Permitting • Cost/kWh • Reliability • Access	• New energy option for coastal cities • Out of sight
• Feasability • Survivability • Cost/kWh • Reliability • Access • Permitting	• New energy option with facility out of site

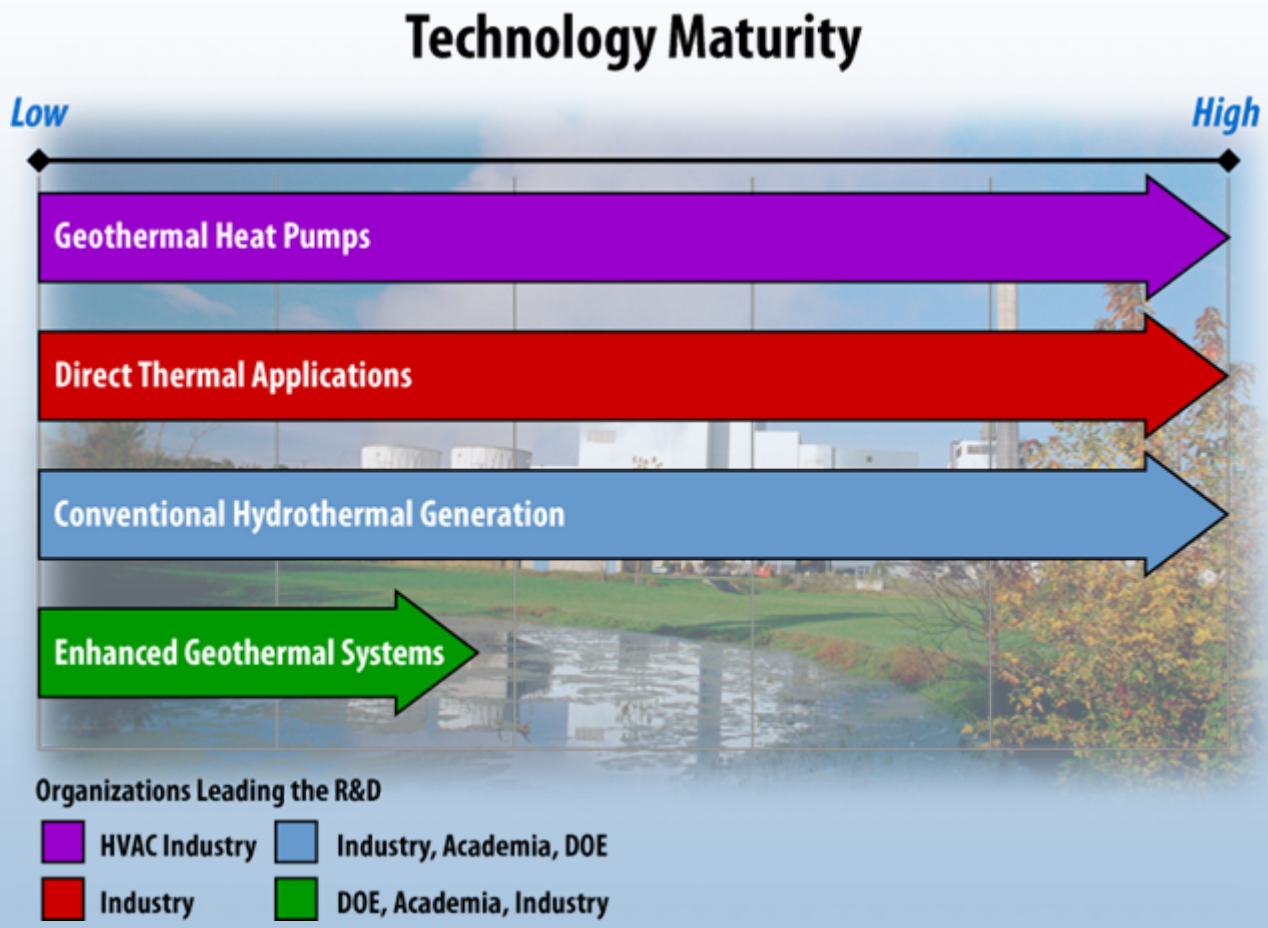
Organizations Leading the R&D

- Industry Leaders with Government Support
- Government Laboratory Contactors
- Goverment-Industry Partnership
- Academia & Small Startups

*Not a DOE Program

Source: NREL 2007

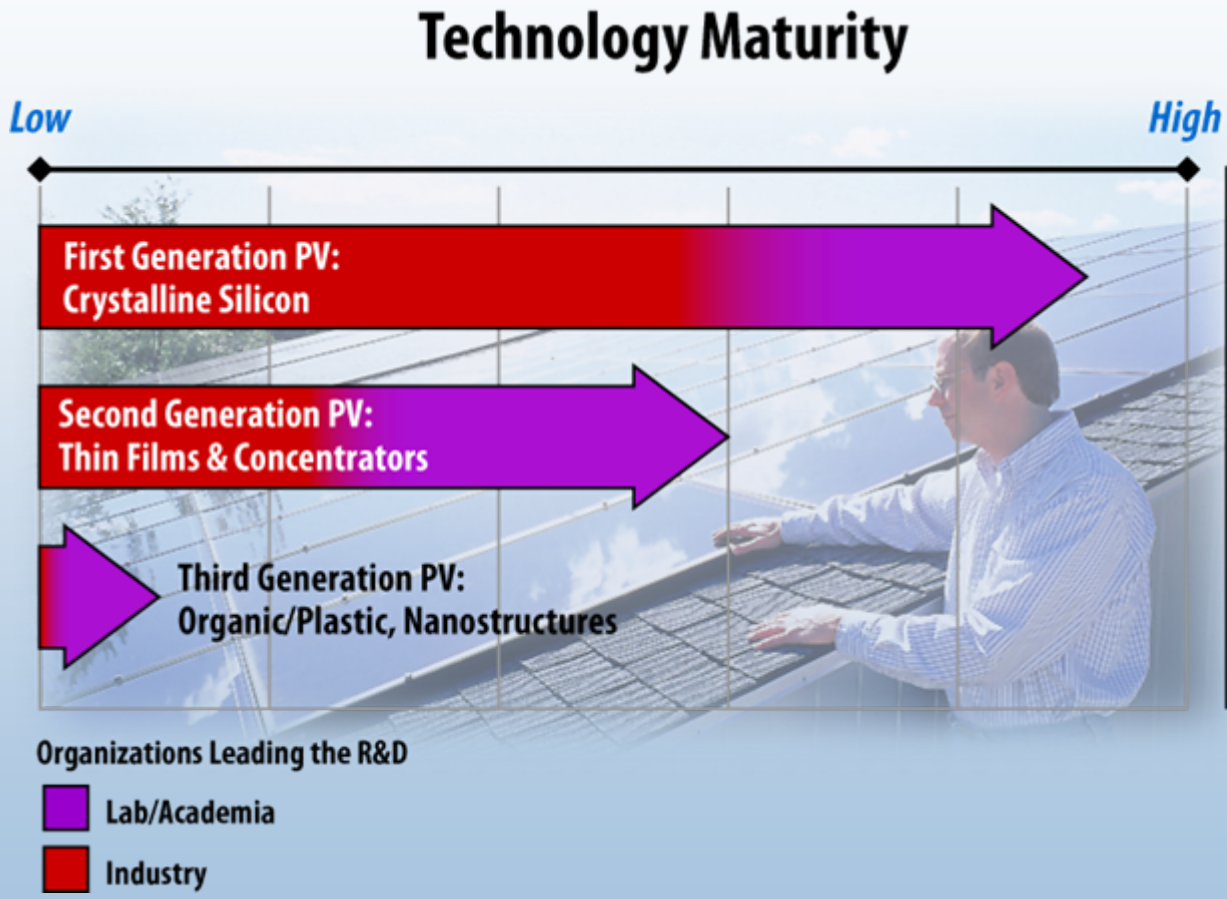
Geothermal R&D



Key Drivers	Attributes
Education, codes and standards to encourage use	Sustainable reduction in life cycle costs and energy use for heating and cooling
Education, outreach	Reduction on fossil fuel use
New explorations techniques and tools	Significant expansion of resource and risk reduction for up to 5% of U.S. electricity production
Advanced reservoir engineering, new drilling paradigm, better power cycles	Less than 10% of national electricity production via geothermal applications across the country could power a hydrogen economy

Source: NREL 2007

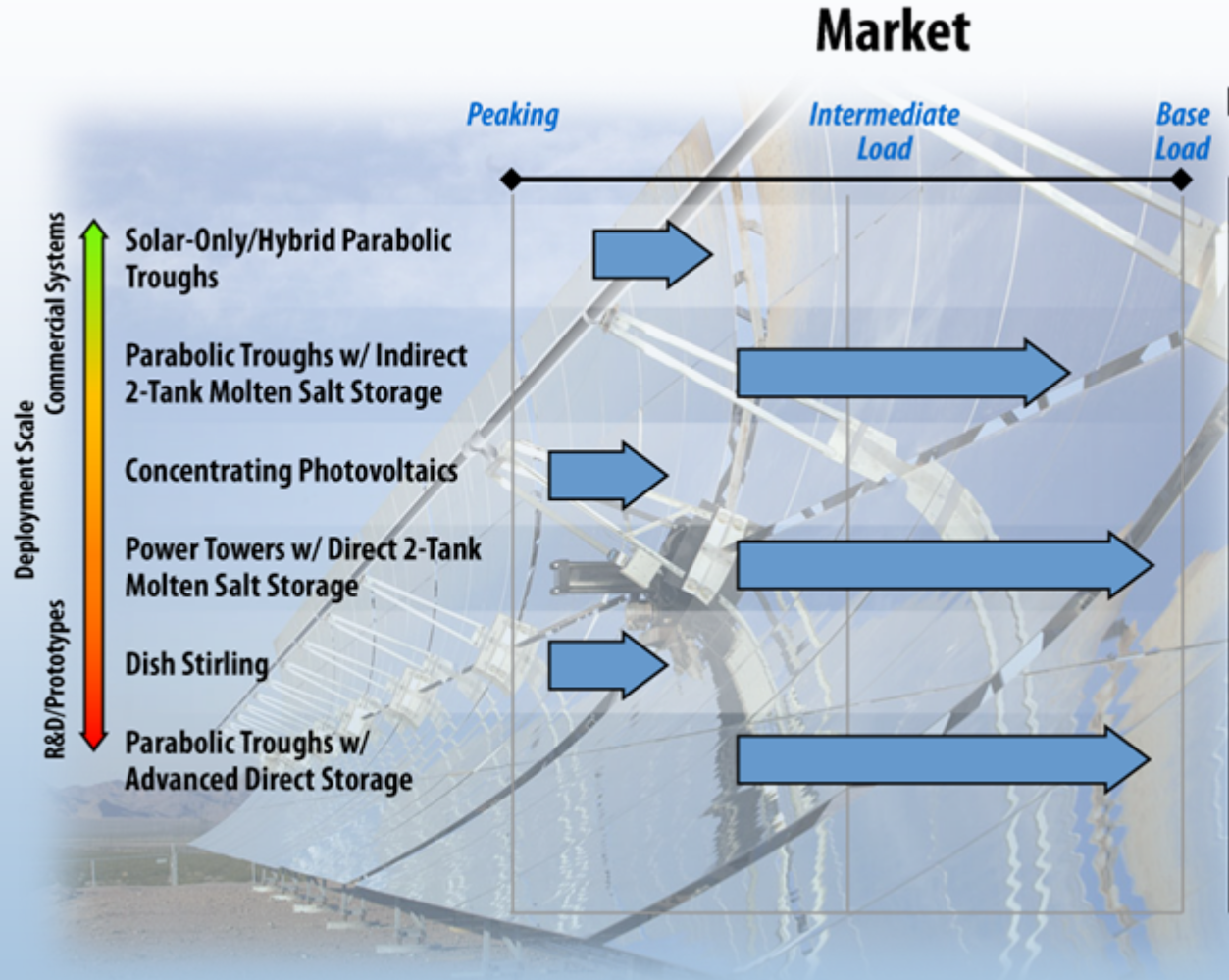
Photovoltaics R&D



Key Drivers	Attributes
Technology based on abundant, well-known semiconductor material also used by electronics industry	Proven manufacturing, solar conversion efficiencies, and long-term durability in the field
Need for lower semiconductor materials usage and lower manufacturing costs	Building integration of thin-film products (flexible or semitransparent); large-scale central power systems (concentrators)
Need for a very high solar conversion efficiencies and/or very low costs	Potential for discovery of new materials and new physical processes for sunlight to electricity conversion

Source: NREL 2007

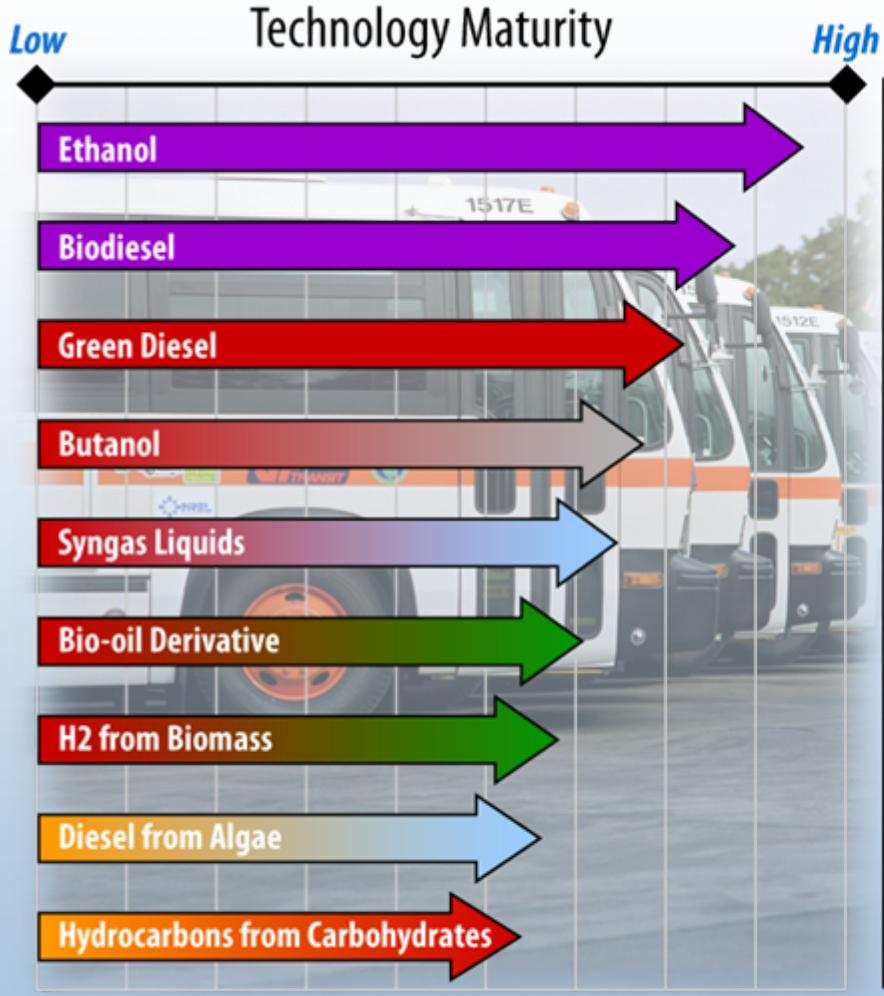
Concentrating Solar Power R&D



Key Technology Drivers	Attributes
• U.S. manufacturing of critical components • Plant capacity • Deployment	• Cost reduction through competition • Cost reductions through learning
• Cost of thermal storage • Established performance record	• Firm capacity value for intermediate load markets • Time shift generation to high value time of delivery (TOD) periods
• Cell cost and performance • Established performance and reliability	• High efficiencies • High reliability (fewer moving parts) • Modular design for distributed or utility markets
• Cost reduction of critical components • Established reliability and performance record	• Firm capacity for intermediate and base load markets • Time shift generation to high value TOD • Low risk thermal storage
• Cost reduction for critical components • Established performance record • Established reliability record	• High efficiency of Stirling engine • Modular design for distributed or utility markets
• Development of advanced heat transfer fluid/storage materials • Development of high temperature receiver materials	• Firm capacity in intermediate and base load markets • Time shift generation to high value TOD • High annual efficiencies

Source: NREL 2007

Biofuels R&D



Key Drivers	Attributes
New market for grain and agriculture products. Large supply of lignocellulose.	High octane gasoline blend stock from carbohydrates.
New market for excess oils, fats, and greases.	Petroleum compatible and biodegradable.
Lower cost and higher product quality than FAME.	Utilize existing assets. High quality jet fuel or diesel.
New market for grain and agriculture products. Large supply of lignocellulose.	Better gasoline blending properties than ethanol.
Integration of biomass with Coal, Coke, Shale, or Heavy Oils.	High quality jet fuel or diesel. Reduced criteria for sequestration, and economy of scale (in combination with fossil).
Technical fit with woody biomass and liquid bio-crude.	Potential to integrate into existing large scale refinery and pipeline infrastructure.
Potential transportation fuel from any fuel/power source.	Ideal feed for fuel cells, and lowest tail pipe emissions.
Lg. source of biomass on non-arable land, and capture of CO^2.	High quality jet fuel or diesel yield per acre, with both off-shore and on-shore potential.
Better compatibility with petroleum products.	Potential for higher reaction rates than fermentation, and potential as H2 carrier.

Renewable Fuels & Low GHG Emissions

Organizations Leading the R&D

- Grain/Agriculture
- Petroleum
- Coal
- Forestry
- Chemical
- Academia & Startups

Source: NREL 2007

Achieving the Right Balance:
Technology Investment Pathways

Source: NREL 2007

Promise of renewable energy is profound and can be realized if we…

- Aggressively seek a global sustainable energy economy
- Accelerate investment in technology innovation
- Commit to consistent and predictable incentives for deployment
- Acknowledge and mitigate the carbon challenge with the necessary policies

It is a matter of national will and leadership